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The Impact of energy performance on single-family house sale prices: A quantitative analysis

ABSTRACT

The building sector accounts for 40 percent of EU's energy consumption. Following an EU directive Swedish real estate owners are obliged to perform an energy assessment of their buildings, for single-family houses particularly upon sale. The Energy Performance Certificates reports the building's energy performance and suggest cost effective measures to improve energy performance. This implies that since 2009 Swedish home buyers have been able to compare energy performance between houses and weigh this information into the buying decision. Using a hedonic price model this paper examines whether better energy performance leads to a higher sales price, and whether the type(s) of suggested efficiency measures have any impact. Results indicate that better energy performance seems to affect sales prices positively. Having had energy efficiency measures suggested seems to have an impact on sales price according to type of measure: home buyers seem to require a larger "rebate" for more complex types of measures. The results also indicate a stronger positive effect on house prices for houses further away from the city centre, and a stronger positive effect for houses built before 1990.

Key-words: Energy efficiency in buildings, property value, hedonic price model, single-family house price

1. INTRODUCTION

Pay attention to the roof if you go to a show in the winter; if the snow stays it´s an indication that the house is well insulated.

The above is an anecdotal example of tips shared among Swedish home buyers to control for thermal qualities of single-family houses, in order to avoid the worst "energy eaters". Another indication of energy performance could be old energy bills, but since 2009 there is yet another method. As a response to the EU Directive 2002/91/EC on the Energy Performance of Buildings (EPBD), all Swedish house owners are now obliged to conduct an Energy Performance Certification (EPC) upon sale of single-family houses. This is one step towards reducing the European building sector's current 40 percent share of total energy consumption, and one of the expectations is that this system will *introduce transparency for prospective owners or users with regard to the energy performance in the Community property market* (EU Directive 2002/91/EC).

Apart from energy costs being a significant component of household expenditures, the question of a building's environmental effect has itself gained importance in property valuation following the last years' climate change debate. To an ever more informed buyer both of these factors should influence the house buying decision. Furthermore, it should be of importance to the (presumptive) home buyer to know whether energy performance can be improved. EPCs include suggestions for cost-effective measures that can be implemented in the building, which serve as information to the presumptive buyers of the building's potential.

By using a hedonic price model, the aim of this paper is to investigate what effect a building's energy performance has on house sale prices. It also examines whether suggested measures for improving energy efficiency, in terms of intervention type (construction, installation or operation/control technical measures), has an effect on sale prices. The hypothesis is that given energy performance of a building, the existence of suggested measures should increase sale price, as it would point to untapped potential. Finally, the possible heterogeneous effects in terms of the house's size, age and location are studied. A wider aim is to contribute to a better market valuation of energy related properties of single-family houses.

Earlier studies have looked at whether energy efficiency measures are capitalized into property value, and the general conclusion is that a more energy efficient building is valued higher by the consumers. However, most of the earlier studies have had to use proxies for energy consumption, such as energy bills (see e.g. Laquatra *et al.*, 2002), which are influenced by consumer behaviour. In this study data is taken from the Swedish EPC register which offers a measure that is adjusted to take into account only the actual building performance, given various circumstances, e.g. geography. Moreover, as the EPCs report all the aspects where efficiency measures have been suggested, it is possible to look at the effect of more than one aspect of energy efficiency, and also to compare their possible effect on sales price. This is in contrast to other studies which have been limited to the effect of single measures, e.g. additional insulation.

The paper begins with a literature review in Section 2, and a brief overview of the EPC system in Section 3. Section 4 continues with describing the methodology and data, and results are presented in Section 5. A discussion is found in Section 6, and Section 7 gives the conclusions.

2. PREVIOUS RESEARCH

Plenty of studies have looked at the effect on house sale prices of energy efficiency, but the larger part of them is growing old. In an overview of 10 hedonic studies made between 1981 and 1999, all for the American single-family house market, Laquatra *et al.* (2002) concluded that the overall results of the studies are as expected; sale prices increase with better energy efficiency. The magnitude of the effect, however, remains an empirical question, as some of the results of the reviewed studies are contradictory or non-satisfactory, and not comparable as they measure different things. As examples among the results for the marginal effects on market value were indications that natural gas heat instead of oil heat led to an increase in market value with 4,597 USD (in 1975), a relatively energy efficient home based on infrared photography would lead to an increase in sales price of 3,416 USD (in 1978-79), storm windows/thermopane glass led to an increase of 407 USD and insulation led to 508-528 USD per additional inch (1980s), and a one-dollar decrease in fuel/utility bills leads to increases in house values of 11.63-20.73 USD (1980s). Laquatra *et al.* also made suggestions for future research, e.g. that energy efficiency, instead of being measured by binary variables indicating the existence of selected energy efficiency attributes (e.g. insulation or a certain fuel type), should be measured by a continuous variable to facilitate interpretation, and would like to see a data base with measures of energy efficiency and a wide range of house characteristics. They also pointed to the need to take into account methodological concerns such as spatial autocorrelation.

Dubin (1992) argued that implicit discount rates for energy efficiency resulting from hedonic estimations are overestimates, because they are reached under the assumption that the home owner will not move from the house, but rather capitalizes all of the investment cost himself. Dubin reviewed four hedonic studies (in two cases overlapping those in Laquatra *et al.* (2002)) which reached implicit values for energy efficiency ranging from 11.63 to 46.64 USD for a one-dollar reduction in annual fuel bills. When combining these implicit values with a method of probabilistic choice, Dubin in his theoretical model concluded that the implicit discount rate depends on the degree of capitalization of energy efficiency improvements *and* on the probability of moving. It is therefore likely to be lower than earlier reports. In his discussion he also mentioned that capitalization rates in general should be higher in colder climates compared to more moderate zones.

Nevin & Watson (1998) found support for the hypothesis of rational market valuations for home energy efficiency. They expected home buyers to be willing to pay between 10 and 25 USD more for every one-dollar reduction in fuel bills, at an after-tax interest rate of 4-10 percent and stable energy price expectations, as this would reflect the present value of energy savings. Using regression analysis on American Housing Survey national data and metropolitan statistical area data, the results of the 45 subsamples (distributed over data source, year, detached/attached homes and fuel type) confirmed the hypothesis, and in many cases turned out to be in the upper limit of the expected range. The hypothesis results were further tested in Nevin *et al.* (1999) when comparing the calculated home value increases for decreased energy bills with the survey results of *Remodeling Magazine*'s appraiser valuation of energy cost savings from window replacement. The calculated model estimates were found to match appraisers' valuations of property value increases fairly well.

Banfi *et al.* (2008) found that the marginal willingness to pay (WTP) as a percentage of purchasing price in Swiss households varied between 1 percent and 13 percent for different energy efficiency attributes. WTP was estimated using a fixed-effects logit model based on a choice experiment with stated preferences. The experiment included both rental housing and home buying, where participants could choose between their current (high or low) standard and a hypothetical housing where energy characteristics (windows, façade and ventilation) differed to the better (worse), and/or price was higher (lower). The trade-off between the overall benefits from housing attributes and prices reveals preferences in a way that can be compared to hedonic price estimates.

Brounen & Kok (2010) have done the first empirical study of the large scale labeling program that is the EPCs. They suggest a price premium of up to 12 percent of sales price for energy efficient homes in the Dutch housing market. The Netherlands were early adopters of EPCs, starting already in 2008, but have implemented a semi-mandatory system, thus enabling a natural experiment. The hedonic analysis included only certified dwellings of all types in a sample of 194,000 observations, and results are based on the seven-stage energy performance categories. From A-rated to G-rated homes there is a steadily decreasing price premium where A-rated homes sell at 12.1 percent higher and F-rated homes sell at 1.8 percent higher than the G-rated baseline homes. Also, homes with a "green" label (categories A-C) sell at on average 6.1 percent higher *ceteris paribus* than other rated homes, but only at 2.8 percent higher when also controlling for building quality. Central heating and better insulation increase transaction price with 1.2-0.9 percent and 0.1-0.2 percent (depending on model specification) respectively. The decreasing price premiums seem to correspond with the present value of future energy savings resulting from improved energy efficiency, indicating that property markets do capitalize energy efficiency investments. The EPCs themselves have been criticized in the Netherlands and Brounen & Kok test whether the price premium is negatively affected over time due to decreasing consumer confidence, but find no support for this hypothesis. Brounen & Kok have also investigated what drives adoption of EPCs, and the results show that building owners are more likely to certify if the building is a single-family house (as opposed to apartment) of moderate size, located in a high-density area where voting for "green" political parties is more common, or if average monthly income is low. It is suggested that sellers use EPCs to resolve the asymmetric information problem in hard competition areas, rather than to signal superior quality.

Entrop *et al*. (2010) use the EPC information to show that, as long as the property value of a building increases, the payback time for energy efficiency investments can be shortened, and that payback time was shorter when indirect benefits from increased property value was included in calculations.

Furthermore, Popescu *et al*. (2009a) and Popescu *et al*. (2009b) have developed methods for taking into account energy performance (as reported in the EPCs) in property valuation using the sales comparison method. The methods are based on comparing the energy performance of the building in question to comparable objects used in the valuation comparison, and to objects in the same category for energy performance reference reasons. In the example calculations using these methods, valuation of "saved" or "wasted" energy (due to improving/not improving energy efficiency) is close to the valuation of energy efficiency improvements.

In Sweden, the authority responsible for implementing the EPCs, the National Board of Housing, Building and Planning (NBHBP), has made a first preliminary evaluation of the EPC system. Telephone interviews were conducted with 700 different actors affected by the new system, among them 100 home buyers. 18 percent of the home buyers said the EPC made a difference in their choice of house, but it was also suggested that the information may have come to the buyer's attention too late in the process. 60 percent had been proposed improvements but 20 percent of them said the sellers already had attended to some of the suggested measures. 78 percent out of the 60 percent who had been suggested improvements said they already knew about the suggestions, 62 percent perceived the suggestions to be profitable and 60 percent had or planned to carry out one or all of the suggested measures. (Boverket, 2009)

In the Swedish housing market, no known hedonic studies relating to energy efficiency have been carried out. However, *Nair et al.* (2010) have reported Swedish single-family house owners' attitudes to investing in energy efficiency measures in the building envelope (windows, attic insulation or wall insulation). The study was based on a survey sent to house owners in 2008, and results show that less than 30 percent of the house owners planned to undertake (building envelope) measures to improve energy efficiency within the next ten years. The factors that were most important in home owners' choice of measure were annual savings in energy costs (mean value of 4.52, on a scale from 1 to 5) and initial investment cost (mean value of 4.42), while environmental benefits (mean value of 3.78), increase in market value of the house (mean value of 3.58) were perceived as less important, and ease of installation, GHG reduction and time required to collect information (mean values of 3.44, 3.38 and 2.85 respectively) were considered yet less important. The study, while not related to the home buying decision, still gives an indication of the state before the EPCs were introduced. They also indicate what factors are more important to home owners regarding energy efficiency which is useful information in trying to predict how the state of energy efficiency in the building stock will evolve in the future.

3. ENERGY PERFORMANCE CERTIFICATES (EPCs)

Following the EPBD, all member countries have been ordered to carry out energy assessments of the building stock. EPCs are a tool for assessing the energy performance of a building and for informing concerned individuals and the public about what can be done to improve the building performance. The EPC is carried out by a qualified, accredited assessor together with the home owner. Throughout Europe the results of the EPCs are communicated with some national differences, where Sweden has chosen to present only the exact performance (expressed as "standard consumption") of the building rather than also placing it in a category. However, comparison values for similar (age-, location- and design-wise) and new buildings (current building standards) are also included for reference.

The EPCs for single-family houses are required when the house is new, up for sale or rent, or when the home owner so wishes. A Swedish EPC is valid for 10 years and report information about (Boverket, 2009):

- house owner,
- location (including information for identification),
- age,
- complexity,
- actual energy consumption,
- distribution of fuel sources,
- electricity use,
- existence of sun panels,
- ventilation control,
- air conditioning system,
- radon content,
- recommended improvements, and
- (if the building earlier has been assessed) information about what measures have been carried out since the last assessment.

Based on the collected information the energy performance is calculated by the assessor.

The suggested improvements are supposed to be cost efficient, i.e. financed by the expected energy savings within the expected life length of the investment. The measures are grouped into three categories. Energy efficiency measures that primarily affect the building envelope are categorized as *construction technical*. In this category the most commonly suggested measures are sealed glazing units for windows, additional insulation (attic joist, floors and sometimes for all of the building), and sealing heat leakages. The measures that address the installations in the building are categorized as *installation technical* measures, and most often refer to replacing the heating source, particularly going from electricity or oil to some kind of heat pump. Water saving measures are also among those commonly recommended. The final category, *operation and control technical measures*, includes measures aimed at optimizing the existing building and equipment. Indoor temperature sensing for control reasons and replacing manual valves for radiators with modern thermostat valves are the most commonly reported. (Boverket, 2009)

4. THEORY, MODEL AND DATA

4.1. The Hedonic Price Model

The hedonic price model for a market with differentiated goods developed by Rosen (1974) has been employed for many years as a means to decompose house prices. The idea is that a house's sale price is a function of its attributes, and the hedonic regression reveals preferences for, and implicit (marginal) values of these attributes. For single-family houses the factors affecting sale price can be divided into categories; property specific attributes, neighborhood specific attributes, location specific attributes, societal factors and personal circumstances. The first two categories mainly concern the actual property and its closest surroundings, such as housing area, lot size, age, accessibility, public transport and view, whereas the last three categories determine the conditions of the housing market concerning more over-arching factors, e.g. the type of city/labor market, land related jurisdiction and household composition or income.

This relationship is modeled in equation 1,

$$y = a + b_1 X + b_2 N + b_3 M \tag{1}$$

where y is the price of the property, X is a vector representing the property specific attributes, vector N represents the neighborhood specific attributes, and M is the vector that represents the surrounding factors on the macro level. To estimate (1) is the basic step in finding out what effect (if any) different factors have on sales price.

As earlier stated, the energy performance of a building directly affects household income negatively through energy bills. Following the last decade's climate debate, it has come to general attention that a building's energy performance also affects the degree to which it contributes to climate change. It should be noted that in this aspect the choice of heating source is also influent. In addition, as energy prices may be volatile, a more energy efficient house can also be seen as insurance against future energy price increases. Following these three factors, it can be assumed that a building's energy performance and its sale price should be negatively correlated to each other, i.e. the more energy efficient the building, the higher the sale price, *ceteris paribus*. This relationship is modeled in equation 2, where E denotes energy performance and is expected to have a negative sign.

$$y = a + b_1 X + b_2 N + b_3 M - b_4 E \qquad (2)$$

Given the energy consumption of a building, the potential to improve energy performance should be seen as something positive, an untapped potential of the building. However, improving energy performance is not always an easy (or cheap) task, which makes the actual effect on price a somewhat open question. The energy certificates report suggestions for what could be done to improve energy performance, which is also included in equation 3. The measures in the first category, construction technical measures, are assumed to be more extensive in nature whereas the measures in the last category, operation and control technical measures, are minor, with little interference to the building. Depending on the intervention, installation technical measures can be more or less interfering with the building. The three factors are included in the model represented by equation 3, where C denotes construction technical measures, I installation technical measures and O is for operation and control technical measures.

$$y = a + b_1 X + b_2 N + b_3 M - b_4 E + b_5 C + b_6 I + b_7 O \qquad (3)$$

4.2. The Econometric Model

Given the logics presented in section 3.1 the model used to investigate the question at hand is described here. The starting point are the results presented in Wilhelmsson. (2004) A log-linear form is chosen to enable elasticity interpretation. The dependent variable is thus the logarithmic form of sales price (first expressed in thousand SEK) for single-family houses.

The building specific variables, vector “X” above, are *building area*[1], *lot size* and *lot size square*, all in logarithmic form. The first two variables are expected to have positive signs; the more square meters, the higher the sales price, while *lot size square* is expected to have a negative sign reflecting the decreasing marginal utility of additional square meters. Moreover, the Swedish Tax Agency’s *quality index* variable is measured on an ordinal scale ranging from 0 to 61, and takes into account various features and the condition of the building. This is expected to have a positive sign; a higher quality score leads to higher sales price, *ceteris paribus*. This variable is partly related to energy efficiency as energy economy is one of the five areas score is given for[2]. The variable *age* is expressed as construction year, and thus expected to have a positive sign; a higher value, i.e. a newer house, is expected to lead to a higher sales price, *ceteris paribus*. However, *age square* is included to control for the fact that older buildings can be seen as possessing a certain charm and thus is expected to have a negative sign. The final variable in *X* is *detached*, a dummy variable indicating that the building is detached as opposed to attached houses of any kind (e.g. row houses and semi-detached houses). This variable is expected to have a positive sign, as it is assumed that people appreciate not having to share their space.
The neighborhood specific factors are captured through dummy variables *o1-o87* for each “value area” according to the Swedish Tax Agency. The value areas are classified after taken into account similar circumstances, such as sea view, noise and distance from city centre. There are in total 86 value areas (o5 was dropped as no observations belonged to it), out of which one randomly serves as a default area to which the other value areas are compared against.

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[1] Including all of the living area plus 20 percent of the by-area that can be reached from within the house.
[2] The other four areas are *exterior*, *kitchen*, *sanitary* and *other interior*.

As all of the observations are from the municipality of Stockholm, no variables are included to control for macro level factors; the observations are all assumed to be affected similarly by the type and state of the economy and the political system.

Finally, the variables relating to energy performance are included in the model. The energy performance variable itself in logarithmic form, expected to have a negative sign as higher energy consumption should lead to a lower sales price. The dummy variables indicating if and what kind of improvements that have been suggested; *operation and control* technical, *installation* technical or *construction* technical, are the last ones in the model. The expected positive sign is because of the untapped potential assumption, *ceteris paribus.*

To be able to explain the variation in sale price that is caused by energy performance all other factors that also affect sales price should be controlled for. In this case there is one variable, *design*, that may have an effect on sales price but also potentially affects energy performance. If the house was designed by an architect, it may have an extra price premium owing to this. But a well designed house may also have been attended to extra carefully regarding energy related features, thereby lowering energy consumption *and* making it more attractive in general. A high performance building (which consumes little energy) could thus be attributed the price effect even though it really should be attributed to design. On the other hand, features of a building that increase energy consumption but are seen as positive enough to also increase house prices, e.g. panorama windows, would have the opposite effect. Should this be a problem there is a case of omitted variable bias, leading to the energy performance estimate being too high (or too low if thinking of the panorama window example). In this model however, the hope is that the age variable capture most of the possible "design" effect in terms of what building norms were prevailing when the house was constructed. Also the quality index variable should take up some of this potential effect as a designed house could be better taken care of, thereby raising the quality index score.

That said, equation 4 shows the relationship that is to be estimated.

$$\begin{aligned} ln(pris) = {} & \alpha + \beta_1 * ln(area) + \beta_2 * ln(lot) - \beta_3 * ln(lot^2) + \beta_4 * qualityindex + \\ & \beta_5 * age + \beta_6 * age^2 + \beta_7 * detached + \beta_8 * o1 - o87 - \beta_{10} * ln(energyperformance) \\ & (+ \beta_{11} * operationcontrol + \beta_{12} * installation + \beta_{13} * construction) + \varepsilon \end{aligned} \tag{4}$$

4.3. Data

For the purpose of this study, data from two sources have been combined into one cross-sectional data set. The first source is the Swedish company Värderingsdata ("Appraisal data") which collects information on all Swedish house transactions. The data received for this study contained all transactions for single-family houses that took place in the municipality of Stockholm, Sweden in 2009. Among the characteristics included in the set are price, building area, lot size, x and y coordinates and a quality index for the building. The second source is the National Board of Housing, Building and Planning (NBHBP), the responsible authority for implementing and surveying the EPCs. The NBHBP compiles all the information collected through the EPCs, which includes energy performance, reference values, suggested improvement measures and measured energy consumption distributed over fuel type. So called high performance buildings of sustainable/green building type (certified by third party) may be included in the sample, but are not specifically labeled. The observations were matched based on address information and the final data set contains 1073 observations. Table 1 shows an overview of the data.

Table 1: Descriptive statistics

Variable	Obs	Mean	Std. deviation	Min	Max
Sale price (kSEK)	1073	4128.47	1801.754	1250	17000
Area (sqm)	1073	127.3504	35.94474	48	360
Lot size (sqm)	1073	531.6272	285.8965	90	1763
Quality index	1073	28.10345	3.833221	19	52
Age (construction year)	1073	1956.11	17.99085	1929[3]	2006
Detached house	1073	.5964585	.4908363	0	1
Energy performance kWh/sqm/year	1073	130.7782	63.38881	13	600
Operation and control technical measure	1073	.1789376	.3834788	0	1
Installation technical measure	1073	.5573159	.4969356	0	1
Construction technical measure	1073	.3671948	.482265	0	1

The average sale price for the houses in the sample was 4.1 million SEK, with observations ranging from 1.25 millon to 17 million SEK. The average building area was 127 square meters, and the average lot sixe was 531 square meters. The quality index points ranged from 19 to 52 points with an average rating of 28.1, and approximately 60 percent of the houses in the sample were detached houses. Concerning energy features, there is a wide range in energy performance, from minimum 13 to maximum 600 kWh per square meter and year. The average energy performance is 130.8 kWh per square meter and year, which can be compared to the new building standard in Sweden, which in 2009 was 110 kWh per square meter and year[4]. Finally, 18 percent of the houses had been recommended operation and control technical improving measures, 56 percent had been recommended installation technical measures and 37 percent had been recommended construction technical measures (the categories are not mutually exclusive).

As can be in table 2, price is relatively highly correlated with *area*, *lot size* and *detached*, and with a somewhat surprising negative correlation also with *age*. In the latter case it looks like the effect of ancient charm is stronger than the effect of a new building. Energy performance is negatively correlated to building size, but has an almost surprisingly low correlation with age, as one may have suspected that older buildings would have poorer energy performance. Also, correlation is weak between energy performance and the three types of suggested measures, and even shows a negative relationship between energy performance and installation technical measures.

Table 2: Correlation matrix

	price	area	lot size	quality index	age	detached	energy performance	control/ operation	installation
area	0.482								
lot size	0.480	0.341							
quality index	0.216	0.332	0.169						
age	-0.497	0.130	-0.337	0.167					
detached	0.634	0.116	0.614	0.128	-0.524				
energy performance	-0.104	-0.201	-0.032	-0.123	-0.119	0.050			
control/operation	-0.044	-0.065	-0.048	-0.103	-0.071	-0.047	0.046		
installation	0.015	0.035	0.042	-0.029	-0.073	0.043	-0.045	0.005	
construction	-0.089	-0.040	-0.024	-0.029	-0.061	-0.004	0.060	0.174	0.185

[3] Buildings in the sample constructed before 1929 had already been assigned 1929 as construction year as a default value upon delivery of data.
[4] Concerns Swedish climate zone III which Stockholm belongs to according to the NBHBP’s division.

5. RESULTS

5.1. The basic model

The hedonic regression of housing attributes on sales price, excluding energy related characteristics, can be seen in the second column (OLS1) in table 3. All continuous variables including price are estimated in logarithmic form. The regression suffers from heteroskedasticity which thus is corrected for in the following regressions (third column onwards). All coefficient estimations are significant on the 1 percent level, and all but age[5] have the expected signs. However, as noted in section 4.3., the unexpected correlation is most likely due to the "ancient charm" effect mentioned earlier.

Table 3: Regression results

Dependent variable: price	OLS1	OLS1, robust**	OLS2, robust**	OLS3, robust**
R^2	0.8922	0.8922	0.8949	0.8977
Chi-square*	5.13			
Constant	319.34360	319.34360	307.16520	290.74990
	(5.39)	(4.59)	(4.43)	(4.29)
Area	0.43794	0.43794	0.42361	0.42670
	(19.79)	(17.75)	(17.26)	(17.48)
Lot area	1.80e-07	1.80e-07	1.74e-07	1.69e-07
	(4.34)	(4.00)	(3.91)	(3.76)
Lot size square	-4.96e-14	-4.96e-14	-4.72e-14	-4.55e-14
	(-2.61)	(-2.63)	(-2.52)	(-2.39)
Quality index	0.00776	0.00776	0.00741	0.00705
	(6.34)	(5.77)	(5.50)	(5.30)
Age	-0.31988	-0.31988	-0.30758	-0.29064
	(-5.29)	(-4.50)	(-4.34)	(-4.19)
Age square	0.00008	0.00008	0.00008	0.00007
	(5.28)	(4.50)	(4.34)	(4.19)
Detached	0.14086	0.14086	0.14642	0.14556
	(7.40)	(6.99)	(7.38)	(7.36)
Energy performance			-0.04455	-0.04406
			(-4.46)	(-4.52)
Operation/control				-0.02429
				(-2.22)
Installation				-0.02319
				(-2.67)
Construction				-0.02695
				(-2.94)
o_{1-87}	Yes	Yes	Yes	Yes

(t-values in parenthesis)
**Breusch-Pagan / Cook-Weisberg test for heteroskedasticity*
***Using White's heteroskedasticity-consistent standard errors (White, 1980)*
Models were all tested for spatial autocorrelation, but no such autocorrelation was found. As an example, using 5, 10 and 15 neighbors for model 2 the resulting Moran's I statistics were 0.70487, 0.69353 and 0.70426 respectively.

In the first model, area has the largest marginal economic effect; a one percent increase in area (square metres) increases sales price with on average 0.44 percent. For each year older the house is, it increases house prices with on average 0.32 percent, and a detached house sells for 0.14

[5] Age was also included as a dummy variable for each decade, which did not turn out significant.

percent more than an attached house *ceteris paribus*. The marginal increase on price of one additional score on the quality index is 0.008 percent on average.

5.2. The effect on price of energy performance

Adding the energy performance variable to the regression can be seen in the fourth column of table 3 (OLS2). The energy performance estimate is significant on the 1 percent level, and the results indicate that for a one percent improvement in energy efficiency, the marginal increase in sale price is 0.04 percent on average. For the average sample house this means that a ten percent improvement in energy performance, i.e. a reduction in energy consumption from 130.8 kWh to 117.7 kWh per square meter and year, would increase sale price with 18,392 SEK. The obtained results of this regression support the earlier stated hypothesis that better energy performance should lead to a higher sales price of single-family houses. Adding the energy performance variable marginally increases the explanation power, coefficient estimates are only somewhat altered, but with the same signs and still significant on the 1 percent level.

5.3. The effect of suggested improvements

In the last step the three types of improvements are added to the regression. If the suggestions, given energy performance, are seen as an untapped potential the three dummy variables representing the categories of measures would have a positive sign; the advice on what to (cost-effectively) improve would increases sale price. However, when looking at the fifth column of table 3 (OLS3) all of the three types of measures have negative signs, with significance levels of at least 5 percent. This indicates that the trouble it causes having to go through with energy efficiency improvements is still seen as a burden that requires a rebate, despite the supposed cost efficiency of the measures.

Based on this perhaps it can be seen as logical that the results indicates that the more uncertain (least significant) of the three variables estimates is for operation and control technical measures, which is the more easily implemented category – if effort is what matters and this effect is low, it may have less or no effect on sale price. Homebuyers nonetheless seem to require a rebate of 0.024 percent of sales price if there are recommendations for such interventions.

There is, however, logics in the indications of the order of the other two variables, where the estimate for installation technical measures, -0.023, is lower than the estimate for construction technical measures, -0.027. Installation technical measures do require some effort on behalf of the home owner, and therefore it would make sense that home buyers require a rebate, but depending on type of intervention the effort may be more or less extensive. Also, measures in this category may have already been thought of even before seeing the EPC, thereby reducing mental resistance. One possible explanation could be that replacing oil heat with an alternative source is widely carried out in Sweden partly due to earlier governmental subsidies, hence making it a known and accepted intervention despite the trouble it means to replace. Construction technical measures on the other hand require more intervention as it primarily is the building envelope that is affected, and therefore the required rebate would be bigger.

5.4. Heterogeneous effects on sales price within different groups of houses

Dummy variables were created within the sample, to look for heterogeneous effects. The first dummy, *central*, was created by assigning 1 to the houses that were located in the areas directly adjacent to the central parts of Stockholm, which was almost 3 percent of the sample, as can be seen in table 4. The second was for *big* houses, and the line was drawn at 200 square meter or more[6], thereby dividing slightly less than 4 percent of the sample into this category. Three age related dummies were also created; *old* houses, constructed before 1930, *relatively old*, constructed in or after 1970 (to a large extent after the oil crisis) and *new* houses, constructed in or after 1990. According to this division almost 11 percent of the sample are *old*, 27 percent of the sample are *relatively old* and 2 percent of the sample are *new*.

Table 4: Descriptive statistics of house groups with different characteristics

Variable	Obs	Mean	Std. deviation
Central	1073	0. 02796	0.16493
Big	1073	0. 03728	0.18953
Old(<1930)	1073	0.10718	0.30948
Rel. new(>1969)	1073	0.27027	0.44431
New (>1989)	1073	0.02050	0.14178

These variables were then multiplied with the (logarithmic form of the) energy performance variable and included in the regression. The results can be seen in table 5.

Table 5: Heterogeneous regression results

Dependent variable: price	OLS4, r**	OLS5, r**	OLS6, r**	OLS7, r**	OLS8, r**
Constant	303.1246	306.6995	360.4759	336.4073	193.8733
	(4.37)	(4.42)	(4.37)	(4.54)	(2.39)
Area	0.42593	0.42800	0.42626	0.426102	0.42928
	(17.31)	(16.33)	(17.07)	(17.30)	(17.39)
Lot area	1.69e-07	1.74e-07	1.67e-07	1.71e-07	1.64e-07
	(3.79)	(3.92)	(3.69)	(3.85)	(3.70)
Lot size square	-4.60e-14	-4.71e-14	-4.39e-14	-4.68e-14	-4.40e-14
	(-2.46)	(-2.53)	(-2.31)	(-2.51)	(-2.37)
Quality index	0.00743	0.00743	0.00751	0.00746	0.00744
	(5.60)	(5.52)	(5.57)	(5.53)	(5.50)
Age	-0.30343	-0.30711	-0.36170	-0.33779	-0.19126
	(-4.29)	(-4.33)	(-4.30)	(-4.45)	(5.50)
Age square	0.00008	0.00008	0.00009	0.00009	0.00005
	(4.28)	(4.33)	(4.31)	(4.45)	(2.29)
Detached	0.14860	0.14601	0.14619	0.14709	0.14560
	(7.52)	(7.34)	(7.40)	(7.42)	(7.36)
Energy performance	-0.04389	-0.04432	-0.04335	-0.04335	-0.04354
	(-4.39)	(-4.43)	(-4.36)	(-4.31)	(-4.38)
Central*energy	0.01794				
	(1.94)				
Big*energy		-0.00290			
		(0.613)			
Old*energy			-0.00672		
			(-1.25)		
>1970*energy				-0.00486	
				(-1.10)	
New*energy					0.02438
					(2.53)
o_{1-87}	Yes	Yes	Yes	Yes	Yes

(t-values in parenthesis)
***Using White's heteroskedasticity-consistent standard errors (White, 1980)*

[6] The average Swedish house in 2009 had a living area (note not "building area") of 124 square meter.

Looking at the first regression which includes the interaction dummy for central houses, OLS4, the estimate for *central*energy* is positive and almost significant on the 5 percent level. The value of the estimate is 0.018. This indicates that besides the negative effect of 0.044 percent for all houses, each percent improvement in energy efficiency lowers sales price on the marginal with on average 0.018 percent, a total of 0.062 percent. This is an indication that the further away from the city center, the bigger the importance of energy efficiency. One possible explanation may be that home buyers in less central areas have stricter budget constraints and hence appreciate lower energy costs more than home buyers of central homes. Perhaps there is also a connection between caring about the environment and wanting to live "closer to nature", but this effect should be marginal.

The interaction variable for big houses (*big*energy*, OLS5) is not significant, indicating that the importance of energy efficiency on average is the same to home buyers irrespective of how big house they prefer/can afford to buy.

Neither the variable for old houses (*old*energy,* OLS6) nor the one for relatively new houses (*>1970*energy* OLS7) are significant, but the variable for new houses (*new*energy*, OLS8) is. The estimate is positive and indicates that a one percent lowered energy consumption increases sales price with 0.024 percent on the marginal. Home owners thus seem to consider energy efficiency to be more important when buying a house older than from the last two decades, and this effect in addition to the average effect seems to reach a total of 0.068 percent.

6. DISCUSSION

Swedish home buyers do seem to take into account the information about energy performance that the EPCs offer, and attribute a price premium to energy efficiency, which is in line with earlier general conclusions (Laquatra *et. al.*, 2002; Dubin, 1992; Nevin & Watson, 1998; Banfi, 2008) but also with early indications of the EPC system in particular (Brounen & Kok, 2010). This price premium seems to be even higher in less central areas, and for houses older than 20 years. As the evaluation the NBHBP (Boverket, 2009) made suggested not all of the home buyers had the information early enough in the buying phase for it to affect outcome, this effect may possibly be bigger in the future if home buyers become more aware. This however presupposes that the assessments are well performed so that buyers feel the information they get is accurate and valuable, which did not seem to be the case for all home buyers according to the early evaluations (Boverket, 2009), which in turn could lead to home buyers losing confidence in the EPC, as Brounen & Kok (2010) expressed fear they may do.

The results indicate that suggested improvements not necessarily are seen as untapped potential by home buyers, but rather seem to be perceived as a burden which home buyers require compensation for. It seems to be that the more extensive the intervention, the bigger the premium, at least when comparing the estimated effect for installation technical measures and construction technical measures. In this comparison the first type gives rise to a smaller price rebate than the latter. The size of the required average rebate for operation and control technical measures seem to be between that for installation technical and construction technical measures. This is somewhat surprising, but different types of suggestions within the three categories may imply different levels of effort (and also different investment costs and different energy savings). The variable itself does not say anything about the extension or number of measures included among recommendations, hence variation within these variables could lead to different impact on buyers. Also, home owners may value payback time or initial investment cost differently than the assessors do.

It is not known whether the more energy efficient houses in the sample are so because of earlier performed energy efficiency improvements or because of better initial quality and/or conditions. Buyers, however, have the information of earlier performed energy efficiency measures in the EPCs, which itself may have an effect; if measures have already been undertaken it may be seen as if the easy solutions are already implemented, leaving only the more extensive ones, which would require more rebate. To know whether the easy or hard measures are left, deeper studies of the EPCs than was possible in this study are required.

A critique that can be addressed to the model is that all houses in this sample are treated alike irrespective of heating source. What type of heating source is installed may be of importance both for environmentally aware home buyers and for cost aware home buyers. Heating source is indirectly included in the quality index variable, but only to a certain point, and without it being possible to control specifically for. It could be interesting to build upon the results in this study, and see whether different fuel types makes a difference in deciding what effect energy performance has, either because of the environmental effect or because of an energy cost effect as different fuel types have different price.

Another interesting question for further research would be to look at a larger geographical sample to see if there are regional differences in Sweden similar to what Dubin (1992) suggested. As more studies are carried out in the EU, it is of course of interest to see if the effect of EPC information on sale price differs throughout Europe.

Also, some energy efficiency improvements add to the Swedish Tax Agency's quality index score, which in turn increases home owners' property tax. There is currently a property tax roof in Sweden but this has not always been the case and is not necessarily so in the future. It would therefore be interesting to know whether home owners perceive this as a trade-off between improving energy efficiency and getting higher property tax (below the tax roof the principle is still valid). At least the results in this study indicate that improved energy efficiency can lead to a higher market value, which perhaps offsets the possible effect of higher property tax. Results from these estimations of price effect can also be coupled with the effect of subsidies for energy efficiency, in order to evaluate the efficiency of the system.

7. CONCLUSIONS

This study has investigated the effect of energy performance on single-family house prices, using a hedonic price analysis. The results indicate that home buyers do take into account the information available in the EPCs, and attribute a price premium to energy efficiency. The marginal effect of a one percent decrease in energy consumption is an increase in sales price with on average 0.044 percent. The total marginal effect on sales price for a house in less central areas is on average 0.062 percent, and for houses built before 1990 the total marginal effect is on average 0.068 percent. Suggestions to improve energy efficiency require further rebate on sale price, in addition to the 0.044 percent effect on sale price. Suggestions in the category operation and control technical measures on average lowers sale price with 0.024 percent, installation technical measures on average lowers sales price with 0.023 percent, and construction technical measures on average lowers sales price with 0.027 percent. The overall conclusions support earlier findings. Suggestions for further elaboration of the results include distinguishing between fuel types, using a sample covering a wider geographical area and examining relation to surrounding institutional factors.

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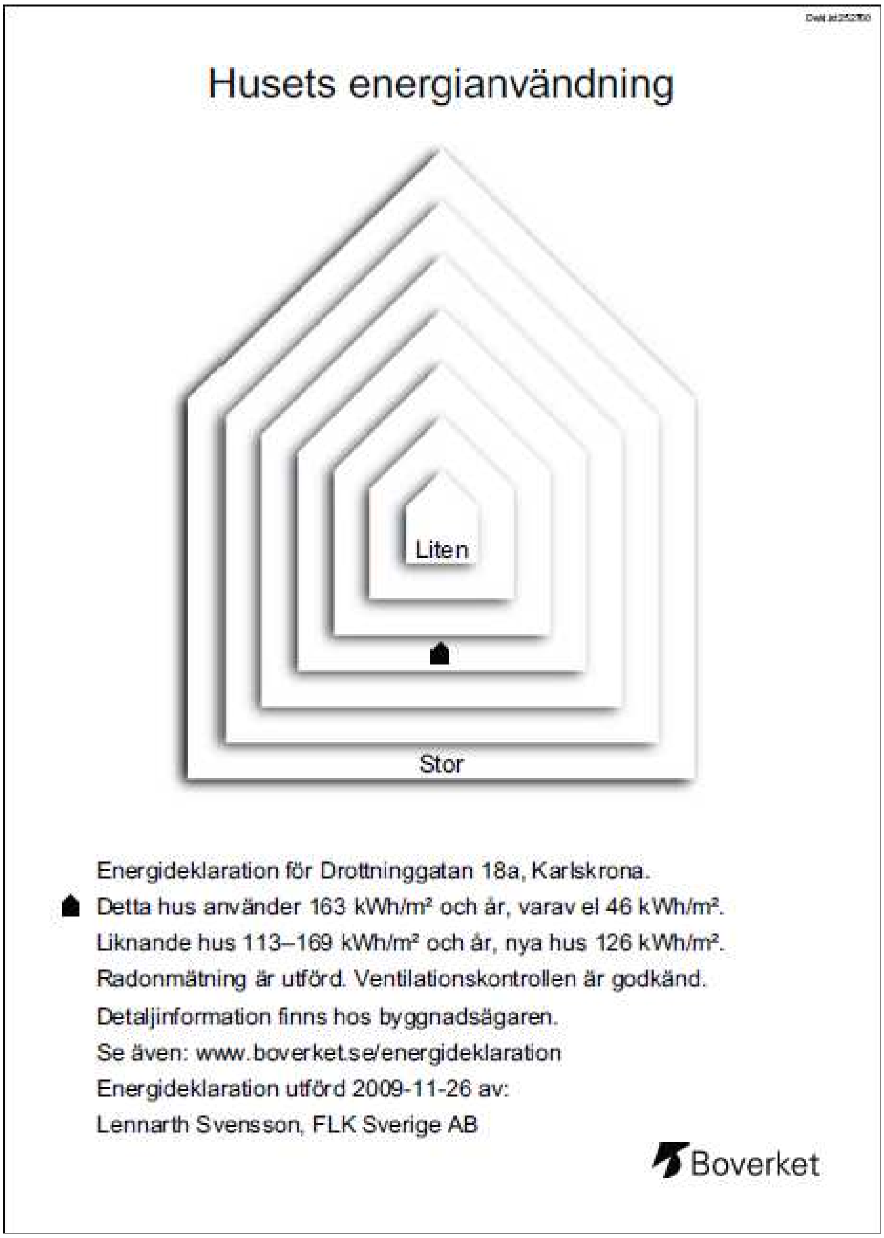
Appendix A
Example of Energy Performance Certificate in Sweden


Husets energianvändning

Liten

Stor

Energideklaration för Drottninggatan 18a, Karlskrona.
Detta hus använder 163 kWh/m² och år, varav el 46 kWh/m².
Liknande hus 113–169 kWh/m² och år, nya hus 126 kWh/m².
Radonmätning är utförd. Ventilationskontrollen är godkänd.
Detaljinformation finns hos byggnadsägaren.
Se även: www.boverket.se/energideklaration
Energideklaration utförd 2009-11-26 av:
Lennarth Svensson, FLK Sverige AB

Boverket

Translation
Energy consumption of the building
Small
Large

Energy Performance Certificate for [address].
This building consumes 163 kWh/square metre and year, out of which electricity 46 kWh/square metre.
Similar buildings consume 113-169 kWh/square metre and year, new buildings consume 126 kWh/square metre.
Radon measuring performed. Ventilation control is approved.
Detailed information can be found with building owner.
See also: www.boverket.se/energideklaration
Energy assessment performed 2009-11-26 by:
[Qualified, accredited assessor]